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PARAMETRIC STUDY ON POLYSTYRENE SHEET IN CONCRETE

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ABSTRACT

Now a days, we all are feeling higher degree of heat in concrete building. So, it is necessary to find solution to reduce temperature of house. The solution is, we can use polystyrene sheet in concrete block, which can help to reduce temperature inside the house. But at a same time, we are facing problem with the compressive strength. So, we are using glass fiber to improve compressive strength. In this study, we have usedM20, M25, M30, M35 grade of concrete. Also, we have used Alccofine 1203 in concrete to improve bonding between concrete & polystyrene. In this study, we have used expanded polystyrene sheet between concrete layers and prepared a "Thermoblock". Ultimately we have tested this block for compressive strength.

KEYWORDS: Expanded Polystyrene (EPS), Alccofine 1203, Glass Fiber, Thermoblock & Compressive Strength

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Original Article

1. INTRODUCTION

Concrete technology is growing and many advances and innovations have been made to cope with challenges of many construction aspects. Many productions of lightweight concrete had been designed and among them are by the use of lightweight aggregates and artificial aggregates such as fly ash and slag [1]. This project aims at producing lightweight concrete by using the expandable polystyrene. Polystyrene is picked because of its lightweight properties, with great vitality retaining trademark and great warm cover driving fundamentally to non-basic applications [2].

In around the world population increases, the demand for energy and raw materials is growing at a greater pace and has led to the greenhouse gas effect that is responsible to the global climate change. The need for new ecological balance has run to researches into the approval of materials that are eco-friendlier and this has taken about better adoption of plastic based materials in the construction industry.

Expanded polystyrene represents one of such materials that have found their way into the previously conservative construction industry.

Lightweight polystyrene Sandwich block which provides rapid or faster construction and contributes to environmental protection, can provide a solution to many of the above issues and concerns. Heat from sun-based radiation which goes through the divider builds the cooling load. Utilization of stage change material on dividers is probably going to diminish the heat rate by putting away vitality when the stage change process happens.

- About Expanded Polystyrene, Alccofine 1203 and glass fiber

1.1 About Polystyrene

EPS is a shut cell lightweight cell plastics material created from polystyrene. The material has been changed by the expansion of fire-resistant added substances. Polystyrene literally translated is "polymerised styrene".

That is, the single styrene molecules are chemically joined together to form a large molecule which is called the polymer [4]. Styrene is delivered from benzene and ethylene, and polymerisation is refined within the sight of substance operator, typically natural peroxides. The expandable shape is delivered as little dots containing a blowing specialist.

Polystyrene is a vinyl polymer. Fundamentally, it is a long hydrocarbon chain, with a phenyl amass appended to each other carbon particle. Polystyrene is delivered by free extreme vinyl polymerization, from the monomer styrene.

Expandable polystyrene (EPS) then is polystyrene in crude dots being steam-warmed, making it extend. Polystyrene has been used mainly in cold countries to make concrete blocks for residential purposes [1].

Expanded Polystyrene (EPS) is a lightweight rigid foam material that is made by the polymerization of styrene nuts and beans.

EPS is a valuable solid material that offers phenomenal protection properties. As the structure of EPS comprises of 98% air its underlying warm properties are kept up amid its working life. It can be manufactured in a wide range of shapes and sizes [9]. Expanded Polystyrene offers a non-hydroscopic and does not readily absorb moisture from the atmosphere. Its shut cell structure diminishes ingestion and movement of dampness it is scentless, inflexible, shut cell Expanded Polystyrene containing 98% by its volume still air entangled in its cell and is the major reason for its excellent insulation properties [9].

For insulation purpose used of polystyrene major properties of considered like, light weight, High strength, economy, good insulation, Design Versatility, Safety in installation and use, Low Thermal Conductivity would be greater performance.

1.2 Alccofine 1203

Alccofine 1203 is ultrafine low calcium silicate product with high glass content with high reactivity obtained through the process of controlled granulation [20]. It improves alkanity of concrete. It is one sort of GGBS (Ground Granulated Blast Furnace Slag), which is altered by different synthetic substances which gives more prominent functionality and makes thick pores in concrete. Alccofine 1203 is a mineral additive with low calcium silicate[21]. Due to pozzolanic reactivity, it results intensified hydration processes, including latent hydraulic property. Alccofine 1203 grows better pressing thickness of paste creation. It improves strength of concrete parameters at all ages. It is very fine based on Particle Size Distribution (PSD) 12000 cm2 / gm[19]. Alccofine has purchased from Ambuja cements and the physical and chemical properties listed below in Table 1 and Table 2

Table 1: Chemical Properties of Alccofine

Chemical Analysis	Mass %
Cao	32-34
Al2O3	18-20
Fe2O3	1.8-2
SO3	0.3-0.7
MgO	8-10
SiO2	33-35

Table 2: Physical Properties of Alccofine

Physical Analysis	Range
Bulk Density	600-700 kg/m3
Surface Area	12000 cm2/gm
Particle shape	Irregular
Particle Size, D10	< 2 μ
D50	< 5μ
D90	< 9 μ

1.3 Glass Fiber

Glass fiber is formed when thin strands of silica based or other formulation glass are extruded into many fibers with small diameters suitable for textile processing. It is material made from extremely fine fibers of glass is a lightweight, extremely strong, and robust material. Its mass quality and weight properties are likewise extremely great when contrasted with metals.

Workability: Glass Fiber used in concrete is reduction in workability. Workability of glass fiber reinforced concrete is affected by fiber aspect ratio and volume fraction as well the workability of plain concrete. As fiber content increase, workability decreases [6].

- Properties of glass fiber[5]
- **Thermal**

Glass filaments are valuable warm separators due to their high proportion of surface region to weight. In any case, the expanded surface territory makes them substantially more susceptible to chemical attack. By trapping air within them, blocks of glass fiber make good thermal insulation, with a thermal conductivity of the order of 0.05W/(m°K).

- **Tensile**

The strength of glass is usually tested and reported for pristine fibers, those that have manufactured. The thinnest fibers are the strongest because the thinner fibers are more ductile.

The present research work is to improve compressive strength when adoption of expanded polystyrene sheet in concrete block.

2. EXPERIMENTAL WORK

Following materials with different function have fulfilled following criteria:

Expanded Polystyrene: Reduce temperature inside face of wall.

Glass Fiber: Repair cracks and better bonding between concrete particles.

Alccofine 1203: Improve better compressive strength when absence of polystyrene volume of concrete deduce.

Figure 1 shows sample of polystyrene sheet and Figure 2 shows polystyrene sheet with reinforcement ring.

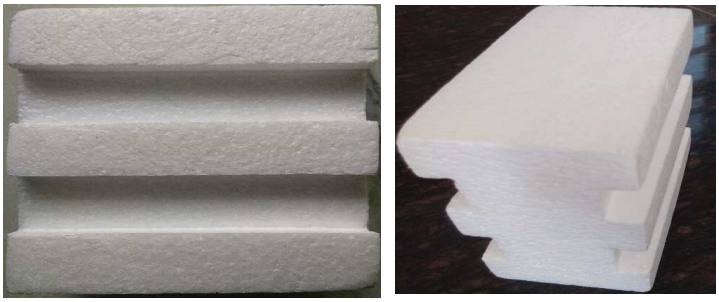

Figure 1: Sample for Polystyrene Sheet

Casting Face **Testing Face**

Figure 2: Sample for Polystyrene Sheet with Reinforcement Ring

Figure. 3 and Figure. 4 show casting manor and cross-sectional view of cube.

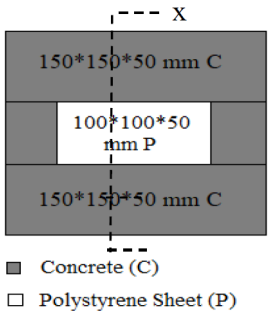

Figure 3: Casting Face of Concrete

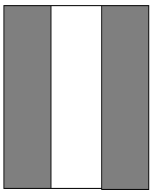

Figure 4: Section View x-x or Testing Face of Block

2.1 Mix Design

Mix design was performed for M20, M25, M30, M35 grade concrete followed by IS 10262:2009. Mix design for different Grades mentioned in table 3.

Table 3: Composition Mix in kg/m^3

		M20	M25	M30	M35	M35R
Cement kg		345.61	394	428.3	469.1	469.0
Coarse Aggregate Kg	10 mm	1073.3	628.5	617.6	604.5	603.82
	16	-	419.0	411.7	403.0	402.5
Fine Aggregate Kg		719.66	702.3	690.1	675.5	674.7
Water Lit.		197	197	197	197	197
Alccofine 1203 Kg		17.28	19.7	21.41	23.45	28.14
GlassFiber Kg		5.18	5.91	6.42	7.03	4.69

2.2 Casting

Cubes of Dimension 150*150*150 mm are casted according to the mix proportion and by using Glass fiber and Alccofine 1203.

2.3 Sample Combination

Compressive assessment is carried out on different samples as listed below,

- **G:** Glass fiber polystyrene sheet concrete block –contains 1.5% fiber.
- **AG:** Alccofine 1203 fiber polystyrene sheet concrete block– contains 1.5% fiber and 5% Alccofine.
- **AGR:** Alccofine 1203 fiber with reinforced polystyrene sheet concrete block- contains 1% fiber and 6% Alccofine with reinforced ring covered at polystyrene sheet.

2.4 Tests

2.4.1 Compressive Strength Test

Compression test is carried out on cube specimens of size (150*150*150). After filling concrete into molds at 1st layer 50mm thick with tamped by tamping rod. After that fill 100*100*50 mm H grade polystyrene sheet at center of mold and equal fill side space of polystyrene sheet fixed. As well as top layer covered by concrete proper tamping. Molds are vibrated properly in order to avoid the air voids in concrete. Specimens are tested on compression testing machine after 7, 14 and 28 days of curing.

Testing results are compared to the strength of two bricks. Because of the volume of two brick at similar to the concrete block and its wall unit criteria. As per Indian standard brick strength 7 N/mm^2.

3. RESULTS AND DISCUSSIONS

3.1 Self-Weight of Composition

We have measure self-weight of normal concrete cube, polystyrene concrete cube and two brick to ensure to the weight of the specimen.

Here, three types of composition to compare weight specified as,

Brick: Weight of two brick because of the similar to the volume of a cube.

PC: Average weight of Polystyrene concrete cube at 28 day

NC: Average weight of the normal concrete cube at 28 day

Sample weight value plotted graph in Figure. 5 and listed in table 4.

Table 4: Composition Weight

Sr. No.		Average Weight KG
1	Brick	6.26
2	PC	6.77
3	NC	7.76

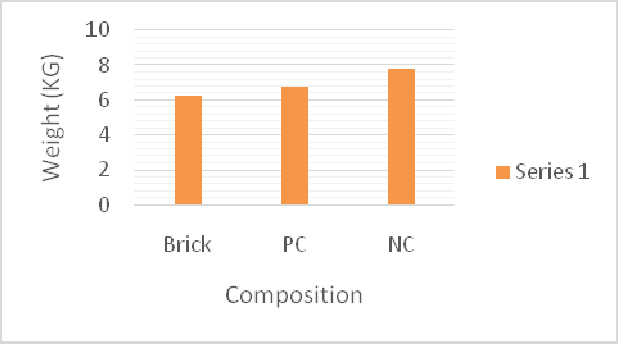

Figure 5: Composition Weight Graph

In this study, to measure the polystyrene concrete cube weight similar to the brick weight and reduced the weight as compared to the normal concrete cube. So, polystyrene concrete cubes another option to brick.

3.2 Compressive Strength Result

Compressive Strength result as per calculation listed below in table 5 and plotted graph shown in Figure 6. Here, we have done the compressive tests on different cubes, and we got the average result for different composition for cubes as below:

- For M30 grade two composition M30 G and M30 AG made. In that case, we are getting very less compressive strength for M30 G (9.67 N/mm^2) with respect to M30 AG (21.80 N/mm^2).
- For M35 grade two composition M35 AG and M35 AGR are made. In this case, we are getting better result for M35 AGR (30.65 N/mm^2) with respect to M35 AG (21.34N/mm^2).
- As compared to Brick, M20 and M25 AG cubes give less or similar result of compressive strength. So, we had tried for M30 and M35 in accordance with better result.

Table 5: Compressive Strength Result

	M20 (AG)	M25 (AG)	M30 (G)	M30 (AG)	M35 (AG)	M35 (AGR)
	Two brick compressive strength 14 N/mm^2					
7 Day	7.63	15.76	6.64	10.29	11.94	16.70
14 Day	9.08	22.86	7.33	17.89	16.13	26.19
28 Day	12.33	24.37	9.67	21.80	21.34	30.65

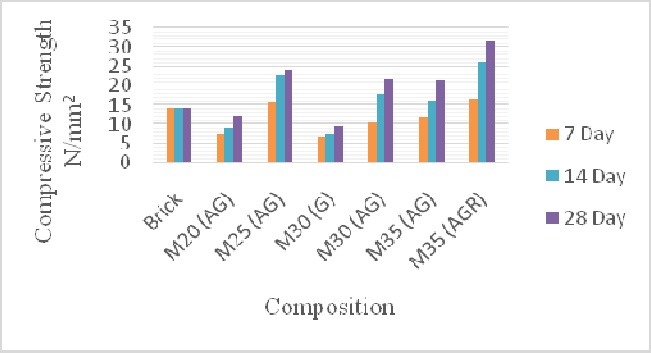

Figure 6: Compressive Strength

3.3 Thermal Conductivity Test

To perform the thermal conductivity test by composite wall method procedure was given below,

- Diameter of slabs (d)

  Base of Concrete: - 0.20m

  Polystyrene: -0.20m

  Top of Concrete: - 0.20m

- **Thickness of slab (b):** - 0.075m
- **Heater:** - 400W
- **Thickness of Base of concrete plate:** - 0.025m
- **Thickness of Polystyrene:** - 0.025m
- **Thickness of Top concrete Plate:** - 0.025m
- **Temperature Indicator:** - 0 - 300ºC
- **Ammeter:** - 0 – 5A
- **Voltmeter:** - 0 – 300V

Composite wall Diagram as shown in Figure 7 for guided actual setup of composite wall slab.

3.4 Procedure

- Arrange the plates in proper fashion (symmetrical) on both sides of the heater plates.
- See that plates are symmetrically arranged on both sides of the heater plates.
- Operate the hand press properly to ensure perfect contact between the plates.
- Close the box by cover sheet to achieve steady environmental conditions.
- Switch on the supply of heater.
- Give known steady input to the heater with the help of dimmerstat.

- Keep initially 100 V for 20 minutes almost and then reduce to 80 V till steady state is reached so that steady state can be reached within less time.
- Check the input to the heater with selector switch, voltmeter & ammeter.
- Note down the temperature every 5 minutes till a steady condition is reached.
- Calculate the thermal resistance of the material based on the steady state condition.

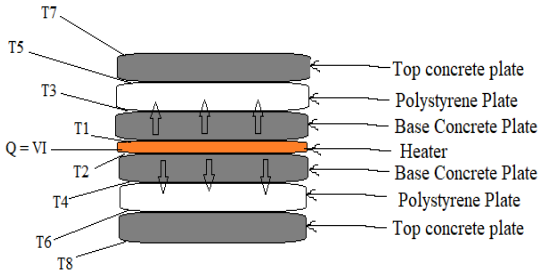

Figure 7: Composite Wall Diagram

Figure 8: Steady State Composite Wall Apparatus

As per shown in Figure. 7,

Where,

T1 and T2 = Centre of plate surface

T3 and T4 = Outside of cast Base concrete Plate/ Inside of Polystyrene Plate

T5 and T6 = Outside of Polystyrene Plate/ Inside of Top concrete Plate

T7 and T8 = Outside of Top concrete Plate

Table 6: Temperature Reduction Measurement

Voltmeter Reading (V): 106						
Ammeter Reading (I): 0.9						
Thermocouple Readings (°C)	**Time (min)**					
	5	**10**	**15**	**20**	**25**	**30**
T1	60	62	65	68	69	69
T2	60	62	64	68	70	70
T3	59	61	63	67	69	69
T4	58	60	63	66	69	69
T5	40	41	42	43	44	44
T6	40	41	42	42	44	44
T7	38	40	41	42	43	43
T8	38	39	41	42	43	43

Testing results of thermal conductivity test listed in table 6 calculation as,

3.4.1 Rate of heat supply

$$Q = V \times I$$

$$= 106 \times 0.9$$

$$Q = 95.4 \text{ W}$$

$$Ta = \frac{T1+T2}{2} = \frac{69+70}{2} \quad Tb = \frac{T3+T4}{2} = \frac{69+69}{2}$$

$Ta = 69.5$ $Tb = 69$

$$Tc = \frac{T5+T6}{2} = \frac{44+44}{2} \quad Td = \frac{T7+T8}{2} = \frac{43+43}{2}$$

$Tc = 44$ $Td = 43$

3.4.2 Total Thermal Resistance of Composite Slab

- $Rh_1 = \frac{Ta-Tb}{Q} = \frac{69.5-69}{95.4}$

  $Rh_1 = 0.0052$

- $Rh_2 = \frac{Tb-Tc}{Q} = \frac{69-44}{95.4}$

  $Rh_2 = 0.26$

- $Rh_3 = \frac{Tc-Td}{Q} = \frac{44-43}{95.4}$

  $Rh_3 = 0.010$

3.4.3 Thermal Conductivity of Individual Materials

- $Rh_1 = \frac{L_1}{K_1 A}$

  $0.0052 = \frac{2.5}{K_1 \frac{\pi}{4}(20)^2}$

  $K_1 = 1.63$ W/m.°K

- $Rh_2 = \frac{L_2}{K_2 A}$

  $0.262 = \frac{2.5}{K_2 \frac{\pi}{4}(20)^2}$

  $K_2 = 0.030$ W/m.°K

- $Rh_3 = \frac{L_3}{K_3 A}$

  $0.010 = \frac{2.5}{K_3 \frac{\pi}{4}(20)^2}$

  $K_3 = 0.80$ W/m.°K

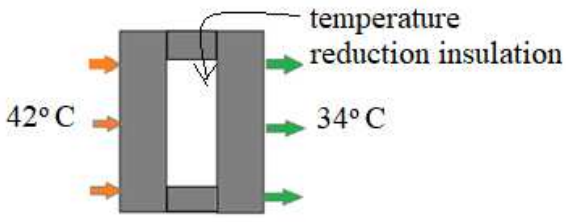

Figure 9: Approximate Temperature Reduction

- After perform the Thermal Conductivity test to measure the thermal conductivity of top concrete plate, Polystyrene plate, Base concrete plate is 0.80, 0.030, 1.63 W/m.°K respectively.
- In composite wall slab 7.5 cm thickness for temperature reduction approximately 26^{o} C Temperature difference between top slab to base slab. After measure the test we are compare to polystyrene concrete cube approximately 7^{o} C to 9^{o} C temperature reduction.
- If we have casted Polystyrene concrete cube wall, in that case possible to adopt plaster thickness less than given higher Degree of temperature reduced. Because of the plaster surface more conserve & store the heat.

3.5 Cost of Concrete Cube

Here, we were calculated the cost of concrete cube and compare to the normal concrete cube. Table 7, Table 8, and Table 9 demonstrate the cost of different composition.

Table 7: M30 Grade Cost for one Polystyrene Concrete Cube

Sr. No.	Material	Today's Market Price (Rs.)	Unit	Requirement in One Cube	Unit	Total Rate in One Cube (Rs.)
1	Cement	300	50 kg	1.20	Kg	7.2
2	Sand	550	1 Ton	2.6	Kg	1.43
3	Aggregate	850	1 Ton	3.2	Kg	2.72
4	Alccofine 1203	23	1 kg	62	Gm	1.43
5	Glass Fiber	80	1 kg	19	Gm	1.52
6	Expanded Polystyrene cube (H Grade)	---------	---------	1	One cube	4
					Total	**Rs. 18**

*Approximate value

Table 8: M30 Grade Cost for one Normal Concrete Cube

Sr. No.	Material	Today's Market Price (Rs.)	Unit	Requirement in One Cube	Unit	Total Rate in One Cube (Rs.)
1	Cement	300	50 kg	1.44	Kg	8.64
2	Sand	550	1 Ton	3.45	Kg	4.3
3	Aggregate	850	1 Ton	4.80	Kg	5.7
4	Alccofine 1203	23	1 kg	73	Gm	1.70
5	Glass Fiber	80	1 kg	21	Gm	1.68
					Total	**Rs. 22**

*Approximate value

Table 9: M35 R Grade Cost for One Polystyrene with Reinforcement Ring Concrete Cube

Sr. No.	Material	Today's Market Price (Rs.)	Unit	Requirement in One Cube	Unit	Total rate in One Cube (Rs.)
1	Cement	300	50 kg	1.58	Kg	11.38
2	Sand	550	1 Ton	2.27	Kg	1.43
3	Aggregate	850	1 Ton	3.39	Kg	2.88
4	Alccofine 1203	23	1 kg	95	Gm	2.18
5	Glass Fiber	80	1 kg	15	Gm	1.2
6	Expanded Polystyrene cube	---------	---------	1	One cube	4

	(H Grade)					
7	Reinforcement	2	Meter	5	Meter	10
					Total	**Rs. 33**

*Approximate value

- Cost of Polystyrene concrete cube less as compare to Normal concrete cube. If cost of concrete cube compared to the brick, higher to the brick. But, plaster thickness of polystyrene concrete cube is half to the brick that should be possible to reduce cost and maintain the total cost.
- Cost of Polystyrene with reinforcement ring concrete cube as compared to brick very higher. But It should adopt when higher load bearing wall to reduce the thickness of wall is good option.

4. CONCLUSIONS

- Alccofine shows better compressive strength of polystyrene concrete block, when volume of cube reduces due to EPS sheet.
- As per result, M30 grade Glass fiber polystyrene Concrete cube (G) compressive strength 9.67 N/mm^2 and Alccofine with glass fiber polystyrene concrete cube (AG) compressive strength 21.60 N/mm^2 at 28 days.
- M15 grade and M20 grade of concrete cube compressive Strength result very less as compared to brick strength so, that should not be adopted to replace of brick.
- M25, M30 and M35 grade of Alccofine with Glass fiber concrete cube (AG) compressive strength result positive to the brick. But, higher load transfer wall M35 grade AGR concrete cube compressive strength result (30.65 N/mm^2) much better than all other test results.
- If Polystyrene concrete cube adopted, to reduce the 7^o C to 9^o C temperature reduce inside temperature. So, It can reduce the energy cost and make an Eco-friendly product.
- Glass fiber protect the failure of cube through cracks and Alccofine increase compressive strength of cube with excellent bonding that can be measured through the test.
- In any load bearing wall, we can replace the brick with this type of concrete block to improve strength and to reduce the room temperature.
- The relative cost of polystyrene, Alccofine and glass fiber is cheaper than the nominal concrete block due to 15% reduction in volume of concrete.

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